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POST-HARVEST DAMAGE AND SUBSEQUENT SURVIVAL FOLLOWING SELECTION HARVESTING OF SMALL UNDERSTORY TREES IN A MIXED CONIFER–HARDWOOD FOREST IN HOKKAIDO ISLAND, NORTHERN JAPAN

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Abstract: *Maintaining abundance and diversity in understory trees after harvesting is important for sustainable management and biodiversity conservation in mixed conifer–hardwood forests in Hokkaido, Japan's most northerly island, where selection harvesting is commonly practiced. However, it has been reported that the abundance and diversity of understory trees following selective harvesting have both generally decreased, and that tree damage ensuing the harvesting is one possible cause. We investigated post-harvest damage and subsequent survival of understory trees of >1.3 m in height and <5 cm in diameter at breast height (dbh) in a mixed conifer–hardwood forest in central Hokkaido Island. We compared the damage for this size class of trees with that for larger size classes, i.e., >5 cm dbh. The rate of damage following harvesting in understory trees was >30% and significantly higher than that due to natural disturbance such as treefall (10%). This difference was particularly pronounced in the rate of devastating damage. The rate of damage following harvesting was high in order for shrubs and for sub-canopy and canopy tree species and it was three to six times higher compared to that seen following natural disturbances. In canopy tree species, the rate of damage in understory trees of <5 cm dbh was higher than for all trees of >5 cm dbh. Furthermore, the survival rate of trees suffering damage induced by harvesting during 5 years following harvesting was significantly lower than that where damage had been induced by natural disturbances or where no damage had occurred. These differences were particularly pronounced in canopy tree species as compared with sub-canopy trees and shrub species. The above findings suggest that damage to residual trees could result in an instant decrease in numbers of understory trees, as well as have a negative impact on the subsequent survival of understory trees.*

1. Introduction

In recent decades, selection harvesting has been concerned as a major alternative to clearcutting and even-aged silvicultural systems (Deal and Tappeiner 2002; Angers et al. 2005; Forget et al. 2007; Burke et al. 2008), because it has been considered to concord sustainable timber production and maintenance of various function in forest ecosystems (Yoshida et al. 2006). In Hokkaido, northern Japan, selection harvesting has been widely employed for managing natural forests since the early twentieth century (Nagaike et al. 1999; Nakagawa et al. 2001; Noguchi and Yoshida 2004; Yoshida et al. 2006). Degradation of natural forests in the region after repeated selection harvesting, which result in inhibition of tree recovery and modification of stand structure, has been empirically recognized among the local forest managers (Ishibashi 1998) and reported in several previous studies (Nagaike et al. 1999; Kitabatake et al. 2003; Noguchi and Yoshida 2004; Yoshida et al. 2006). One notable feature of degradation is decrease of small-sized residual trees, which would be future crop trees (Kuramoto et al. 2008). We consider that one possible cause of this change is the damage of residual trees by cutting and machinery traffics. We already investigated the amount and extent of tree damage by selection harvesting (Sasaki et al. 2005, 2008, 2009). Based on direct investigation of each trees under the census, these preceding studies revealed that significant number of residual trees are injured and totally damaged following one harvesting practice. However, these studies also revealed that a large portion of damage are partial, not devastating. This fact suggests that subsequent decrease of damaged trees should be much considered than instant decrease by devastating damage, as the cause of forest degradation. These instant and subsequent influences of damage are also caused by natural disturbance such as windthrow or treefall, not only by harvesting. However, none of studies investigated the influence of damage by harvesting, based on the comparison to those by natural disturbance. Furthermore, tree census in these studies ignored the young trees, which are smaller than the threshold size for census, although these trees are expected be vulnerable to harvesting damage. In this study, we examine the influence of damage caused by selection harvesting on the small residual trees. We especially focused on the damage of small young trees, and considered subsequent influence of damage (survival). We also revealed the detailed influence of damage to residual small young trees by selection harvesting, based on the comparison to the damage caused by natural disturbance.

2. Material and Methods

Study area

The study was conducted in a mixed conifer-hardwood forest of the Ikutora national forest area in central Hokkaido, northern Japan (elevation ca 500-550 m, 43˚04' N, 142˚40' E). Forests in the region are generally dominated by fir (*Abies sakhaliensis*), spruce (*Picea jezoensis*), maple (*Acer mono*), basswood (*Tilia japonica*), ash (*Fraxinus mandshlica*) and oak (*Quercus crispula*). In December 2002, selection harvesting was conducted in the stand with north-facing gentle slope within the forest. It was the first logging in the stand, and there has been no any record of logging before. Harvesting intensity was 4.3 % in number of trees (25.3 trees to total 593.3 trees per ha), and 21.4 % in stand volume (77.1 m^3 to total 360.1 m^3 per ha), which was decided according to stand volume growth. The tree length skidding systems were used for the harvesting. The operations were performed by conventional systems with fellings and delimbings by manual chain-saws, skiddings by crawler tractors, bunching by grapple loaders, and cross-cuttings by chain-saws.

Field data collection and data analysis

In 2002, prior to logging, a 1.5-ha plot (100 m x 150 m) was established within the stand, within which all trees over 1.3m in height were tugged and surveyed DBH and location at a spatial scale of 10m x 10m grid. Type, extent and cause of damage of each tree were surveyed just after logging. Cause of damage was carefully classified into harvesting and natural disturbance (natural treefall), based on the state of damage and the location to harvested trees or skid trails. Extent of damage was also classified into devastating and partial. In the case trees which were completely uproot, or their trunks were broken, it was considered as devastating damage. In 2007, five years after logging, residual trees were re-surveyed to check their survival. Each species were classified into three life-form types; canopy, sub-canopy, shrub species. Survival rate of residual trees for five years after selection harvesting was calculated for each cause of damage, and life-form type of species.

3. Results and Discussions

Damage of small young trees

Within 1.5-ha plot, 486 small young trees (> 1.3m in height and < 5cm in DBH) were found. 146 (30%) small young trees were damaged by selection harvesting, that was third times higher than 48 (9.9%) damaged trees by natural disturbance such as treefall. Devastating damage by selection harvesting was 96 trees, which was 60% of total damage by selection harvesting. It was also higher than devastating damage by natural treefall (5 trees, 10% to total). The rate of damage following harvesting was high in order for shrubs and for sub-canopy and canopy tree species and it was three to six times higher compared to that seen following natural disturbances (Table 1). Rate of damage of small young trees induced by selection harvesting was higher than those of trees over than 5cm (15.2 %, Sasaki et al. 2005). Rate of devastating damage of small young trees (60%) was also higher than those of trees over than 5cm in DBH (51.5%, Sasaki et al. 2005). Among the trees over 5cm in DBH, damage was highly concentrated smaller size class, i.e. 5 to 8cm in DBH (Sasaki et al. 2005). These facts suggest that rate of damage increased as tree size decreased, and the risk suffering devastating damage also increased as tree size decreased. These damage of small trees considerably higher and would result remarkable decrease of future crop trees.

Table-1. Rate of damage within each life-form type, among small young trees (>1.3m in height and <5cm in DBH)

Life Form	(Number of species)	Injured					No damage
		by harvesting		by natural disturbance		Total	
		All	Devastating	All	Devastating		
Shrub	5	40.1	31.3	13.6	2.0	53.7	46.3
Sub-canopy tree	2	50.0	35.5	8.1	0.0	58.1	41.9
Canopy tree	12	20.2	10.1	8.3	0.7	28.5	71.5
Total	19	30.0	19.8	9.9	1.0	39.9	60.1

Subsequent survival of damaged trees

50 trees suffered partial damage, such as branch-breaking, bending, and debarking. These trees were alive just after harvesting operation. Fate of these 50 trees and 43 trees, which had partial damage by natural treefall, was checked 5 years after harvesting. There was the substantial difference in survival among presence and type of damage (Table 2). Compared with trees, which have no damage, survival of damaged trees remarkably decreased, especially for the case of harvesting-induced damage. These differences were strongly pronounced for canopy trees, compared with sub-canopy and shrub species. It was suggested that harvesting-induced damage provide strong negative influence to survival of small young trees, especially to canopy tree species. This negative impact to survival could enhance the negative impact of damage to small tree assemblage, in addition to immediate devastating damage. Therefore, it was suggest that damage to residual trees could result in an instant decrease in numbers of understory trees, as well as have a negative impact on the subsequent survival of understory trees.

Table-2. Survival rate of damaged and non-damaged small young trees 5 years after selection harvesting.

Life-form	Damaged		No damage
	Harvesting	Natural	
Shrub	33.3	80.0	88.5
Sub-canopy	38.5	35.3	51.5
Canopy	28.6	66.7	92.4
Total	32.0	55.8	82.5

Value is the percent survival of small young trees (> 1.3m in height and < 5 cm in DBH) for each category

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